NVSA Johnson Space Center

BATTERY REVIEW BOARD

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THE 1992 NASA AEROSPACE BATTERY WORKSHOP

NOVEMBER 19, 1992

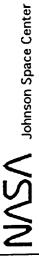
AS A MAN GETS WORKING ON THE SECONDARY BATTERY IT BRINGS OUT HIS LATENT CAPACITY FOR STOCK COMPANIES. THE STORAGE RATTERY IS ONE OF THOSE PECULAR THINGS WHICH APPEAL TO THE IMAGINATION, AND THE STORAGE BATTERY IS, IN MY OPINION, A CATCH-PENNY, A SENSATION, A MECHANISM FOR SWINDLING THE PUBLIC NO MORE PERFECT THING COULD BE DESIRED BY STOCK SWINDLERS THAN THAT VERY SELF-SAME THING....JUST AS SOON LYING...SCIENTIFICALLY, STORAGE IS ALL RIGIIT, BUT, COMMERCIALLY, AS ABSOLUTE A FAILURE AS ONE CAN IMAGINE.

THOMAS A. EDISON - JANUARY 1883

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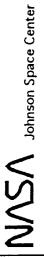
BATTERY REVIEW BOARD

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NASA BATTERY REVIEW BOARD CHARTER

- BATTERIES WITH EMPHASIS ON RELIABILITY, PRODUCIBILITY AND PERFORMANCE REVIEW THE STATUS OF Ni-Cd, Ni-H2 and Ni- METAL HYDRIDE AEROSPACE
- DETERMINE BEST DIRECTION FOR FUTURE NASA PROGRAM WITH RESPECT TO THESE SECONDARY BATTERIES



MEMBERSHIP

CHIEF OF THE PROPULSION AND POWER DIVISION CHAIRMAN, CHESTER A. VAUGHAN

NASA HEADQUARTERS DIRECTOR OF THE TECHNICAL STANDARDS DIVISION MEMBER, DR. DANIEL MULVILLE

MARSHALL SPACE FLIGHT CENTER MEMBER, J. ROY LANIER CHIEF OF THE ELECTRICAL POWER SYSTEMS DIVISION

MEMBER, DR. ALLAN (AL) SHERMAN DEPUTY DIRECTOR OF ENGINEERING

GODDARD SPACE FLIGHT CENTER

LEWIS RESEARCH CENTER DEPUTY CHIEF OF THE ELECTROCHEMICAL TECHNOLOGY BRANCH MEMBER, DR. PATRICIA M. O'DONNELL

JET PROPULSION LABORATORY DEPUTY MANAGER OF THE ELECTRICAL POWER SYSTEMS SECTION MEMBER, DR. C. PERRY BANKSTON

TECHNICAL SECRETARY, BOBBY J. BRAGG

TOM YI DR. GERALD HALPERT JOHN DAY

SHAHID HABIB

ADVISORS:

NASA HEADQUARTERS GODDARD SPACE FLIGHT CENTER

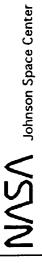
JOHNSON SPACE CENTER

JET PROPULSION LABORATORY



BOARD CHRONOLOGY

BOARD DELIBERATION AND SITE VISIT AT GSFC SITE VISIT AT COMSAT CORPORATION	BOARD TELECON SITE VISIT AT LEWIS RESEARCH CENTER	SITE VISIT AT EAGLE-PICHER INDUSTRIES IN COLORADO SPRINGS, CO	SITE VISIT AT JET PROPULSION LABORATORY	SITE VISIT AT HUGHES, ELECTRON DYNAMICS DIVISION IN TORRANCE, CA	SITE VISIT AT AEROSPACE CORP IN LOS ANGELES, CA	SITE VISIT AT MDESC IN ST. CHARLES, MO	SITE VISIT AT EAGLE-PICHER INDUSTRIES IN JOPLIN, MO
8/19-21/92 8/20/92	8/25/928/28/92	8/31/92	9/1/92	9/2/92	9/2/92	9/9/92	9/10/92



BACKGROUND

- ISSUES ENCOUNTERED MOST APPLICATIONS ABLE TO MANAGE BATTERY PROBLEMS BY REDUCING LARGE NUMBER OF APPLICATIONS IN THE 60'S AND 70'S. SIGNIFICANT BATTERY PERFORMANCE POWER CONSUMPTION AND MANAGING CHARGE CONTROL
- GSFC IMPLEMENTED GSFC STANDARD SPEC AND GROUND TEST APPROACH FOR THE 20 AH CELLS AND BATTERIES
- GSFC CONTRACT WITH FOUR MANUFACTURES (GE, E-P, GULTON, AND YARDNEY) MANUFACTURE OF PELLON 2505 SEPARATOR MATERIAL DISCONTINUED-FOR STANDARD 20 AH CELL. ONLY GE (GATES) PASSED CERTIFICATION 1975 • 1976
- GSFC 50 AH SPEC FOR STANDARD CELLS AND BATTERIES DEVELOPED , LATE 1970'S

CELL/BATTERY COMPANIES STOCKPILE ENOUGH TO LAST THROUGH THE 80'S

- DOWN FOR THREE MONTIIS IN SEPTEMBER OF 1984 TO CORRECT DEFICIENCIES MANY PROBLEMS WITH PLATES AND CELLS AT GE. THEIR COMMERCIAL LINE, WHICH ALSO PRODUCES PLATES FOR AEROSPACE APPLICATIONS, WAS SHUT 1980-85
- BATTERY PROBLEMS NASA AEROSPACE FLIGHT BATTERY STEERING COMMITTEE NASA ADMINISTRATOR (MR. BEGGS) REQUESTED AND RECEIVED SURVEY OF ESTABLISHED - BATTERY PROGRAM PLAN ESTABLISHED 1985
- 1986 GE SOLD TO GATES

BACKGROUND (CONT.)

BATTERY STEERING COMMITTEE CONVERTED GSFC STANDARD SPEC'S AND MCD TO NASA STANDARDS • 1985-91

SEARCH FOR NEW SEPARATOR MATERIAL TO REPLACE PELLON 2505 LED TO DEVELOPMENT OF PELLON 2536 AND 2538 Ni-H2 TECHNOLOGY MATURING - SPACE STATION SELECTED NI-H2 BASELINE

ADVANCED NI-Cd TECHNOLOGY MATURING

GSFC SELECTED ADVANCED NI-Cd (9 AH) FOR SAMPEX APPLICATION

JPL SELECTED 37 AH ADVANCED NI-Cd AS BACKUP FOR MARS OBSERVER

GSFC SELECTED 50 AH ADVANCED NI-Cd AS BACKUP FOR EUVE

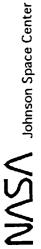
LARGE NUMBER OF SUCCESSFUL FLIGHT PROGRAMS (LEO & GEO) UTILIZING NASA STANDARD NI-Cd BATTERIES (LANDSAT-ERBS, SMM, TIROS) ı 1975-1991

PROBLEMS ENCOUNTERED WITH 50 AH CONVENTIONAL Ni-Cd BATTERIES AND CELLS 11/91 TO PRESENT GSFC HAS SELECTED 50 AH ADVANCED Ni-Cd FOR XTE AND TRMM AND 9 AH ADVANCED Ni-Cd FOR FAST AND TOMS 1



STATEMENT OF PROBLEM

- INSUFFICIENT/NON REPEATABLE Ni-Cd BATTERY CHARGE/DISCHARGE CYCLE CAPABILITY FOR LEO APPLICATIONS
- EARLIEST FAILURE TO DATE ~ 2000 CYCLES; DIVERGENCE > 200 MV
- WHEN DIVERGENCE OCCURS, TLC (TENDER LOVING CARE) CAN PROLONG THE LIFE. HOWEVER, ON EXISTING IN-FLIGHT SPACECRAFT, THERE IS LIMITED BATTERY CHARGE/DISCHARGE CONTROL CAPABILITY.
- CAPABILITY SIGNIFICANT AMOUNT OF TIME REQUIRED TO VALIDATE LIFE CAPABILITY ACCEPTANCE TEST PROCEDURE (ATP) INSUFFICIENT TO SCREEN FOR CYCLE LIFE
- GENERAL CONSENSUS IS THAT THE PROBLEM IS WITH NEGATIVE PLATE
- CELL ELECTRICAL BEHAVIOR AND DPA'S (DESTRUCTIVE PHYSICAL ANALYSIS) OF CELLS FROM GROUND TEST SHOW SYMPTOMS OF A FAILED CELL AT THE END OF ITS LIFE
- ROOT CAUSE OF THE FAILURE IS UNKNOWN



SUMMARY OF PROBLEMS WITH 50 AH STANDARD Ni-Cd

FLIGHT VEHICLES

TWO MODULAR POWER SYSTEMS (MPS); THREE BATTERIES EACH

NOMINAL OPERATION FOR 7 MONTHS (~3000 CYCLES)

DEC 91, ~ 80 MV DIFFERENTIAL

CURRENTLY -

BATTERY 2 OFF LINE > 750 MV MPS 1:

NOMINAL FLIGHT PERFORMANCE MPS 2:

BATTERIES 1 AND 3 (STILL ON LINE 150 - 300 MV)

UARS

1 MPS

NOMINAL OPERATION FOR 2,000 CYCLES

JAN '92 - OCT '92, 80 MV UP TO 400 MV

CURRENTLY - APPROMIMATELY 200 MV

GROUND TEST

GRO

CELLS FROM MPS 1 LOT EXHIBIT CELL DIVERGENCE (30 MV) AFTER 6600 CYCLES; THEN

IMPROVED

CELLS FROM MPS 2 LOT NOMINAL

CELLS FROM FLIGHT LOT EXHIBIT CELL DIVERGENCE AFTER 2000 CYCLES

THREE UARS CELLS DPA'D FROM FLIGHT LOT AT APPROX 5000 CYCLES

• 2 FROM STRESS PACK (EXCESSIVE MIGRATION IN ONE, OTHER WAS NOMINAL)



ACTIVITIES FOR NEAR TERM PROGRAMS UTILIZING CONVENTIONAL Ni-Cd

ASSESSMENT:

UNCERTAINTY ASSOCIATED WITH LEO LIFE CYCLE CAPABILITY OF ALL NASA STANDARD Ni-Cd

RECOMMENDATIONS:

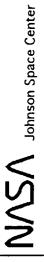
- ON-ORBIT VEHICLES IN LOW EARTH ORBIT MINIMIZE STRESS OF THE BATTERY (TLC)
- MINIMIZE OVERCHARGE AND AVOID HIGH TRICKLE CHARGE CURRENT STRONG EVIDENCE THAT THIS ENHANCES LIFE - THIS SHOULD BE DONE ON ALL PROGRAMS UTILIZING NASA STANDARD NI-Cd BATTERIES
- ACTIVITIES IS ON-GOING. DETAILED SUGGESTIONS HAVE BEEN DISCUSSED WITH THAT GROUP CODE S OPERATIONS COMMITTEE APPOINTED BY DR. FISK TO CO-ORDINATE OPERATIONAL
- CONTINUE SEARCH FOR ROOT CAUSE(S)
- CONTINUE TO PARTICIPATE WITH GOVERNMENT TEAM LOOKING FOR CORRELATION BETWEEN APPARENT GOOD LOTS AND THE PROBLEM LOTS
 - PERFORM CELL DPA'S AT OTHER LOCATIONS
 - MSFC, JPL, LeRC
- RE-EVALUATE PLANNED LAUNCHES UTILIZING ALREADY MANUFACTURED NASA STANDARD Ni-Cd BATTERIES
- PERFORM 2 YEAR CELL STRESS TEST OR A MISSION SIMULATION TEST ON FLIGHT LOT CELLS PRIOR TO FLIGHT

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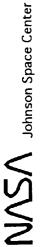
PRESENT PROJECTS SCHEDULED TO USE NASA STANDARD Ni-Cd

BATTERIES MANUFACTURED FROM LOT 14 PLATES; SAMIE AS NOAA D (16 MONTHS IN ORBIT), ONE BATTERY ON II (FOUR + YEARS IN ORBIT); 22 MONTH SUCCESSFUL LIFE TEST. ACCEPTABLE FOR FLIGHT. 22 MONTH MISSION SIM TEST IN PROGRESS; EVALUATING POSSIBLE USE OF SAFT OR SUPER NI-Cd Cd (POSSIBLY M.O.), SAFT NI-Cd AND NI-H2 AS ALTERNATIVES GEO ORBIT MISSION OF APPROXIMATELY 4 YEARS USING 2 NASA STANDARD 19 AH NI-Cd at 50% DOD WITH RECONDITIONING ANE INDIVIDUAL CELL VOLTAGE MONITORING AVAILABLE	3/93 BATTERIES MAN D (16 MONTHE ORB '94 22 MONTH PC '95 24 MONTH MIS Cd (POSSIBLY GEO ORBIT MIS STANDARD 19 INDIVIDU



OTHER NEAR-TERM NASA PROGRAMS REQUIRING SECONDARY BATTERIES

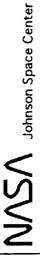
	COMMENT							6.5 YEARS @ 35% DOD	677010 001,002	4755 CYCLES/ 10 YEARS
ERIES	LAUNCH DATE		8/94	6/95 8/94	12/95	8/97 8/97		3/96		96/9
\TTI	АН		6	6	20	50 TBD		81		78
DARY BA	ORBIT		LEO	CHI CHI	LEO	LEO L1		LEO		15-60% DOD FOR .5-1.5 HOURS
REQUIRING SECONDARY BATTERIES	TYPE		Su Ni-Cd	Su Ni-Cd	Su Ni-Cd	Su Ni-Cd TBD		Ni-H2		Ni-H ₂
	BATTERY MANF		HAC	IBD	HAC	HAC		LORAL		MDESC
	CELL		EP-CS	EP-CS	EP-CS	EP-CS TBD		GATES		EP-J
	PROGRAM	GSFC	FAST	TOMS	XTE	TRMM	LeRC	SSF	JSC	TESS



RECOMMENDED DIRECTION FOR FUTURE PROGRAMS

RECOMMENDATION: MAKE SELECTION(S) BASED ON REQUIREMENT TRADE STUDY RESULTS COMBINED WITH MARKET PLACE COMPETITION

- CONVENTIONAL Ni-Cd
- UNLESS ON-GOING ACTIVITY IDENTIFIES ROOT PROBLEM(S) WHICH CAN BE CORRECTED USER BEWARE WITH RESPECT TO NASA STANDARD NI-Cd CELLS FOR LEO APPLICATION
- ADVANCED Ni-Cd
- ACCEPTABLE FOR FLIGHT USAGE
- QUANTITY OF DATA ON ADVANCED Ni-Cd IS LIMITED AND MORE TESTING SHOULD BE PERFORMED
- GROUND HANDLING/STORAGE PROBLEM NEEDS RESOLUTION
- Ni-H₂
- EXCELLENT SYSTEM FOR LEO IN TERMS OF CAPABILITY; (CYCLE LIFE, DEPTH OF DISCHARGE,
- Ni-MH
- MONITOR PROGRESS OF Ni-MII
- EACH PROGRAM SHOULD PERFORM A SPECIFIC BATTERY QUALIFICATION TEST. ALSO PERFORM A MISSION SIMULATION TEST, AND/OR A CELL STRESS TEST ON FLIGHT LOT CELLS PRIOR TO
- CONTROL SYSTEMS TO LIMIT OVERCIIARGE AND GENERALLY MINIMIZE STRESS ON BATTERY PROVIDE MORE FLEXIBLE CHARGE CONTROL AT A BATTERY LEVEL, e.g. DESIGN CHARGE
- DESIGN NI-CA SYSTEMS TO ALLOW FOR RECONDITIONING OF BATTERIES IN LEO IF PRACTICAL



FUTURE CELL/BATTERY PROCUREMENT STRATEGY

ASSESSMENT

AND NASA CONTROL OF A STANDARD MANUFACTURING CONTROL DOCUMENT FOR NI-THE CURRENT STRATEGY OF A NASA STANDARD CELL AND BATTERY SPECIFICATION Cd IS UNWARRANTED

RECOMMENDATIONS

- TREAT BATTERY/CELL LIKE OTHER SPACECRAFT COMPONENTS
- LET PRIME OR IN-HOUSE PROJECT OFFICE (S) DECIDE ON SPECIFICATIONS, MCD'S, ETC. USE CONTRACT INCENTIVES TO INSURE PERFORMANCE, SCHEDULE, AND LIFE
 - CHARACTERISTICS ARE MET
- CHECKLIST/HANDBOOK FOR PROCURING CONVENTIONAL NI-Cd, ADVANCED NI-Cd, BATTERY STEERING COMMITTEE SHOULD REORIENT 8073.1 SPECIFICATION AS A AND Ni-H₂
- RELINQUISH NASA CONTROL OF DASH 87 AND DASH 88 MANUFACTURER'S CONTROL DOCUMENT (MCD)



FUTURE CELL/BATTERY PROCUREMENT STRATEGY (CONT.)

PRO'S

- PLACES RESPONSIBILITY AND ACCOUNTABILITY WITH THE PRIMES AND THEIR SUBCONTRACTORS
- ALLOWS IMPROVEMENTS DEVELOPED IN COMMERCIAL AND OTHER GOVERNMENT PROGRAMS TO BE INCORPORATED INTO NASA PROGRAMS MORE QUICKLY

DECREASES RESPONSE TIME FOR NECESSARY MCD CHANGES AT THE VENDOR

- UTILIZES MARKET PLACE FOR COMPETITION
- ALLOWS NASA AEROSPACE CELLS TO BE MORE LIKE COMMERCIAL AND OTHER GOVERNMENT AEROSPACE CELLS
- MORE LIKE HOW WE ARE CURRENTLY OPERATING

- POTENTIALLY LESS NASA CONTINUITY BETWEEN PROGRAMS
- POTENTIALLY FEWER LONG TERM BUSINESS ARRANGEMENTS
- BATTERY TEAM IN '85 RECOMMENDED USE OF STANDARDS



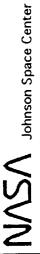
NASA BATTERY PROGRAM

ASSESSMENT:

PROVIDE OVERSIGHT FOR THE NASA BATTERY PROGRAM (INITIALLY FUNDED IN 1988) AND PERFORMS INTEGRATED, WELL MANAGED NASA AEROSPACE BATTERY PROGRAM. THIS GROUP CONTINUES TO THE NASA BATTERY STEERING COMMITTEE WAS ESTABLISHED IN 1985 TO PROVIDE FOR AN AN ESSENTIAL SERVICE FOR NASA AND AEROSPACE BATTERY COMMUNITY

RECOMMENDATIONS:

- CONTINUE BATTERY PROGRAM EVALUATION OF ADVANCED NI-Cd, NI-H2 AND NI-MH CELLS TO SUPPORT FUTURE NASA MISSIONS
- ABANDON THE NASA STANDARD BATTERY CONCEPT WITH RESPECT TO NASA CONTROL OF THE CELL SPECIFICATION AND THE MANUFACTURING CONTROL DOCUMENT
- REVISE NHB 8073.1 (NASA STANDARD CELL SPECIFICATIONS) TO CELL/BATTERY PROCUREMENT GUIDELINES
- FOCUS ON COORDINATION OF LESSONS LEARNED AND MAINTAINING AND UPDATING AGENCY WIDE BATTERY DATA BASES
- EXPAND CURRENT BATTERY PROGRAM PLAN TO INCLUDE AUTOMATED FLIGHT/GROUND TEST, GOVERNMENT AND INDUSTRY CELL/BATTERY DATA BASE
- PROVIDE INDEPENDENT VERIFICATION OF MANUFACTURING FLIGHT CELLS BY PROCURING AND TESTING REPRESENTATIVE CELLS FROM VARIOUS MANUFACTURERS
- AUGMENT LIFE CYCLE TESTING OF GOVERNMENT OWNED EXISTING SUPER AND CONVENTIONAL Ni-Cd
- DEVELOP AN APPLICABLE CELL STRESS TEST FOR Ni-H2 and Ni-MH



SUMMARY

- HISTORICAL REVIEW OF NI-Cd USAGE INDICATES "GOOD OLE DAYS" WERE ONLY PARTIALLY GOOD
- SEVERAL ON-ORBIT AND GROUND TEST CYCLE LIFE PROBLEMS WITH NASA STANDARD Ni-Cd CELLS - ROOT CAUSE REMAINS ELUSIVE
- ON-ORBIT CYCLE LIFE CAN BE PROLONGED WITH TENDER LOVING CARE (TLC)
- SIGNIFICANT NUMBER OF NASA STANDARD NI-CD CELLS ALREADY MANUFACTURED FOR FUTURE APPLICATIONS - EACH PROGRAM IS EVALUATING EXISTING DATA AGAINST SPECIFIC APPLICATION REQUIREMENTS.
- BATTERY CHOICES FOR NEAR-TERM, NEW PROGRAMS INCLUDE Ni-H2, ADV Ni-Cd, AND CONVENTIONAL Ni-Cd

CD ENVIRONMENTAL RULING ACCEPTABLE BUT SHOULD EXPECT CONTINUING PRESSURE

- FUTURE APPLICATIONS SHOULD EMPHASIZE NI-H2
- UNWARRANTED SHOULD ALLOW SPACECRAFT REQUIREMENTS AND MARKET PLACE NASA POLICY FOR IMPLEMENTATION OF NASA STANDARD CELL AND BATTERY COMPETITION TO DRIVE SELECTION

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